SPACE FACILITIES

MEETING FUTURE NEEDS FOR RESEARCH, DEVELOPMENT, AND OPERATIONS

Committee on Space Facilities
Aeronautics and Space Engineering Board
Commission on Engineering and Technical Systems
National Research Council

National Academy Press
Washington, D.C. 1994

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This study was supported by Contract NASW-4003 between the National Academy of Sciences and the National Aeronautics and Space Administration.

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Executive Summary

The environment in which national space activities are conducted has changed significantly in recent years. Technological advances, domestic and foreign policy shifts, economic constraints, and international competition all have affected priorities in the space program and increased options for achieving objectives. This dynamic environment for space activities has important implications for future facilities needs. The National Facilities Study (NFS), initiated in 1992 and completed in May 1994, represents an interagency effort to develop a comprehensive and integrated long-term plan for world-class aeronautical and space facilities that meet current and projected needs for commercial and government aerospace research and development (R&D) and space operations.

At the request of the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD), the National Research Council's Committee on Space Facilities has reviewed the space related findings of the NFS.[1] Given the relatively short time available for the NFS task team and working groups to pull together much information and analysis about the current space facilities infrastructure, the National Research Council committee believes that many aspects of the study were performed very well. The inventory of more than 2,800 facilities will be an important resource, especially if it continues to be updated and maintained as the NFS report recommends. The data in the inventory provide the basis for a much better understanding of the resources available in the national facilities infrastructure, as well as extensive information on which to base rational decisions about current and future facilities needs.

The working groups have used the inventory data and other information to make a set of recommendations that include estimates of cost savings and steps for implementation. The recommendations for change are well reasoned, as far as they go, and merit implementation. However, the NFS space facilities recommendations are driven by current budget constraints rather than a careful and reasoned attempt to predict long-term needs. Although tight federal budgets provide a strong incentive for greater interagency cooperation and for reducing the number of facilities, they provide little incentive for long-term planning. Without a well-articulated nàtional space policy on which to base facilities requirements, emphasis inevitably gets placed on reducing annual operating costs by closing some facilities while modifying and consolidating others. This emphasis is reflected in the NFS space facilities recommendations.

If the NFS is ultimately to respond to the questions posed to its task team, additional work is needed to assess facilities needs in the context of realistic long-term national aspirations in space. In particular, more work is needed in four areas: (1) the requirements models described in the NFS, (2) the efficiencies possible from a serious analysis and realignment of agency roles and missions and management practices, (3) the low level of industrial participation in the space facilities aspects of the NFS, and (4) the implications of future international competition and cooperation for domestic space facilities.

[1] The aeronautics facilities aspects of the NFS are being reviewed by the Aeronautics and Space Engineering Board, whose findings are described in a separate report.

Requirements Models

The NFS baseline model for commercial, civil, and military space systems needs is based on other recent mission models and conforms to current budgetary and policy decisions. It contains no new major missions or vehicles and, therefore, the NFS task team assumes that no major changes in launch facilities or research facilities are needed. The excursion model has some new missions and vehicles, but its implications on facilities are not addressed in the NFS.

The assumption in the baseline model that the status quo will be maintained for the next 30 years is not conducive to a rigorous analysis of future facilities needs. In fact, it is more likely that the space program will undergo major changes in direction and scope during that period. The excursion model is more indicative of what is likely to be needed during this 30-year period, since it explores the development of some new facilities and technology.

Roles and Missions

The NFS recognizes the importance of reviewing and modifying roles and missions within and across agencies and calls for further study. However, possible realignments of roles and missions, and their implications for facilities requirements and costs, did not receive thorough analysis. For instance, opportunities to consolidate activities of the NASA centers, to consolidate Shuttle hardware activities at Kennedy Space Center, and to streamline Air Force launch operations are not sufficiently evaluated in the NFS. The NFS also pays inadequate attention to areas in which management practices have detrimental effects on operational efficiency.

Industrial Participation

Although there was some participation by industry in the facilities inventory, and some effort to gather industry input, the focus of the NFS is almost exclusively on government-owned space facilities. The task groups believed that market forces would dictate decisions on private facilities; indeed, a number have been closed as the aerospace industry retrenches. But current market incentives are such that considerable excess capacity in space facilities may remain. The high costs of closing facilities and the need for contractors to demonstrate that facilities are in place to be competitive on contract bids work together to keep excess facilities open.

International Competition and Cooperation

Foreign facilities will affect U.S. space operations and R&D efforts either by providing opportunities for cooperation or by increasing competition with U.S. facilities and setting standards for cost, reliability, and capability. Many foreign launch facilities are newer and, having benefited from American experience, are designed for operational efficiency and cost-effectiveness. Foreign R&D facilities also are improving. The possibility that international competition and cooperation will affect U.S. space facilities requirements, including potential U.S. reliance on foreign facilities, has not been explicitly addressed in the NFS.

Recommendations

Given the committee's assessment of the mission and requirements models and the NFS analysis of space facilities using the models, much more work should be done to determine national space facilities needs based on more realistic long-term objectives. The committee recognizes that the ability to develop more realistic national space objectives ideally depends on clear policy decisions and budgetary commitments to back those decisions. However, a better assessment of future facilities needs is still possible in their absence. It should be based not only on current trends in technology, international competition, and industry, but also on innovative approaches to meeting mission requirements. Such an assessment would highlight policy alternatives and opportunities to improve the nation's space facilities infrastructure.

The committee, therefore, first recommends that NASA and DoD conduct a second phase or follow-on study. A goal of this study should be not only to illuminate the savings possible from changes in the space facilities infrastructure but also to illustrate the potential to enhance the nation's ability to meet its objectives based on more effective utilization of facilities.[2]

The committee has identified several broad areas that should form the nucleus of this follow-on study. (Additional specific elements that should be addressed in the next phase of the NFS are detailed in the committee's recommendations.)

- The baseline requirements model should be revised to include a set of potential vehicle options and the facilities that would be required to support them. There are a number of possible approaches currently being evaluated to upgrade and modernize U.S. launch capabilities. These approaches include single stage to orbit, liquid and solid technologies, and hybrids of the two. Future facilities needs should take into consideration innovative approaches to reduce operational costs. Such approaches were lacking in the NFS.
- The roles and missions currently allocated within and between NASA and DoD facilities should be reassessed. Where changes in roles and missions also would enable more efficient, effective use of facilities, such facility changes should be recommended.
- The incentives and disincentives facing the aerospace industry that are related to facilities should be identified. A broad set of issues, including tax policy, accounting requirements, and contracting procedures, should be addressed to generate a comprehensive picture of industry's facilities investment behavior. These issues can only be solved by securing much greater industry participation in the process of reviewing national space facilities. Such issues might be covered in any future survey of industry's needs as well.
- Finally, appropriate interactions with foreign countries need to be explicitly examined. The follow-on study should have a clear international element that documents current major R&D and operational facilities abroad, projects likely future capabilities relative to the United States, and identifies conditions under which cooperation is likely or even preferred and those under which separate U.S. capabilities are essential.

Because a broad revision of roles and missions could result in extensive changes in facilities requirements and workloads, and would likely raise political concerns, consideration should be given to establishing a presidential commission, analogous to the Base Realignment and Closure Commission, to help generate the political consensus necessary to close and consolidate some facilities.

Conclusion

While, in today's budget-conscious environment, it is natural that the NFS focused on cost reduction and consolidations, such a study is most useful to future planning if it gives equal weight to guiding the direction of future facilities needed to satisfy legitimate national aspirations. Even in the context of cost reduction through facilities closures and consolidations, the study is timid about recognizing and proposing program changes and realignments of roles and missions to capture what could be significant savings and increased effectiveness. The recommendations of the Committee on Space Facilities are driven by the clear need to be more realistic and precise both in recognizing current incentives and disincentives in the aerospace industry and in forecasting future conditions for U.S. space activities.

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[2] Such a study could build on the current review of NASA and other government laboratories that is being coordinated by the Office of Science and Technology Policy.

1

Introduction

BACKGROUND

The United States' efforts in space began as a natural progression from national programs in aeronautics. In the 1950s, significant funding impetus for the space program resulted as an outgrowth of the Cold War, and continued national support was maintained as the space program became a visual symbol of U.S. technical competence. With the termination of the Cold War, the largest space development agencies, the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA), have been called upon to demonstrate the relevance and effectiveness of their space programs. The Cold War's end coincided with a period of unprecedented federal budget deficits. In a time of severely constrained budgets, the space program faces challenges of accomplishing significant scientific and technical goals while fulfilling international commitments, maintaining national security objectives, and maintaining a competitive commercial posture.

Recognizing the importance of national test and operational facilities in maintaining a strong aerospace sector, as well as the potential economic benefit from possible closings and consolidations, Daniel S. Goldin, Administrator of NASA, initiated the National Facilities Study in 1992. He contacted top officials in the DoD, the Department of Energy, the Department of Transportation, the Department of Commerce, and the National Science Foundation, inviting them to participate in the development of a comprehensive and integrated long-term plan for future aerospace facilities. The leadership of these government agencies nominated individuals to serve on an oversight group and to provide support to an interagency task team. The task team, organized into four task groups, was charged with developing a coordinated national plan for world-class aeronautical and space facilities that meet current and projected needs for commercial and government research and development (R&D) and space operations.[3]

NASA and DoD subsequently requested that the Aeronautics and Space Engineering Board (ASEB) of the National Research Council review and critique the requirements and facility approaches presented in the NFS. The board was asked to assess the extent to which the interagency task team considered alternative facility approaches and to recommend any further actions or studies that should be pursued by the interagency group. To address the space portions of this request, the National Research Council Committee on Space Facilities was formed. (The committee's Statement of Task appears as Appendix A.)

This report responds to Phase 1 of the Statement of Task. It conveys the committee's findings, conclusions, and recommendations.[4]

The committee has focused only on the relevant volumes of the NFS. These include Volume 1: Facilities Inventory, Volume 3: Mission and Requirements Model, Volume 4:

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[3] See, "Terms of Reference, National Facility Plan Development", *National Facilities Study Summary Report*, p. 24.

[4] Phase 2 of the committee's Statement of Task may or may not be undertaken depending on the needs of the sponsor and any further work that may be done by the interagency task team.

Space Operations, and Volume 5: Space R&D.

APPROACH

In addressing its task, the Committee on Space Facilities met in Washington, D.C. on December 9-10, 1993; February 7-8, 1994; and March 9-10, 1994. The committee received briefings on the work of the interagency task team, on the progress of several studies regarding national launch needs that were underway at the time of the space facilities task groups' work, on congressional and administration interests, and from interested individuals in industry. Subsequently, drafts were exchanged and teleconferences held to finalize this report on the committee's findings and recommendations.

2

The Environment

CIVIL AND MILITARY APPROACHES TO FACILITIES

The United States' space program always has been a combination of military and civil activities, with relatively sporadic cooperation and coordination between the two sectors. As mandated by the National Aeronautics and Space Act of 1958, NASA primarily manages civil scientific and human space missions; the DoD, primarily the Air Force and the National Reconnaissance Office, manages military and intelligence applications of space.[5] As the civil and military space sectors have independently grown over more than 35 years, distinct management cultures and operating procedures have emerged.

One tangible manifestation of these cultural differences has been the way facilities have been created and managed. When NASA was first formed, the agency acquired some existing laboratories and facilities, which had a history of integrated operations ranging from research to building and testing equipment; additional test and R&D facilities were added over time. This initial experience created an historical preference within NASA to build needed facilities in-house. As these facilities have become more numerous and complex, NASA has hired contractors to operate some of them, but NASA's facilities remain predominantly owned by NASA. One result of this approach to facilities has been some duplication of capabilities and dispersion of effort across NASA centers.

DoD, in contrast, has encouraged and often funded contractors to build their own facilities as part of the requirements for specific contracts. There are some DoD-owned facilities, but the majority of military space facilities are contractor owned and operated. Encouraging contractors to build facilities in order to bid competitively has led to a proliferation of industry's facilities and, in some companies, significant excess capacity, especially in the current budget environment.

These historic preferences affect operations philosophies. NASA centers, such as Marshall and Goddard Space Flight Centers, as well as the Jet Propulsion Laboratory, have some capability to design, develop, build, and test space hardware themselves. With this capability, NASA can act as both supplier and customer for its test facilities. Often contractors funded by NASA use NASA test facilities. DoD, in contrast, generally expects contractors to have the facilities necessary to meet contractual requirements and therefore relies on industry for its facilities needs.

These two distinct approaches to facilities have important implications for the NFS. The current inventory of space facilities includes a combination of government-owned, government-operated facilities (GOGOs), of which the NASA centers are the best examples; government-owned, contractor-operated facilities (GOCOs), which include the Palmdale and Downey, California Shuttle facilities operated by Rockwell for NASA; and contractor-owned, contractor-operated facilities (COCOs), which include most of the facilities of defense contractors. However, the inventory and analysis in the NFS are heavily weighted toward GOGO and GOCO facilities. The result is that NFS recommendations to close, consolidate, or modify facilities tend to focus on NASA facilities, while defense facilities are expected to be managed by contractors as business decisions taken in the context of rapidly shrinking budgets.

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[5] A few other agencies have been responsible for specific types of payloads, such as the National Oceanographic and Atmospheric Administration's responsibility for weather satellites, but the bulk of federal funding and management responsibility has rested with NASA and DoD.

CHANGING FUNDING ENVIRONMENT

The funding environment for both military and civil space programs has been affected by three main factors. First, the end of the Cold War has caused major and continuing reductions in defense budgets. Second, political support for civil space probably peaked with the Apollo program. Third, efforts to reduce federal budget deficits have increased pressure to cut most federal program budgets, including space programs. As a result, recent federal budgets have not only increased the rate of reduction in the DoD space budget but also have inflicted real cuts in the civil space program. DoD's space budget declined from a peak of almost $18 billion in fiscal year 1988 to less than $14 billion in fiscal year 1994. NASA's budget grew from $9 billion in fiscal year 1988 to over $14 billion in fiscal year 1994,[6] but it is expected to decline to a little more than $12 billion in fiscal year 1999, based on five-year projections from the fiscal year 1995 President's budget request.

The impact of shrinking federal budgets on the aerospace industry has been dramatic. From 1988 to 1994, some 500,000 highly trained workers left the payroll of the U.S. aerospace industry.[7] However, the vast infrastructure of space facilities developed over the past 37 years has not been commensurably reduced to fit the current budget and industrial work force. Although industry recognizes the existing overcapacity, financial and business incentives sometimes discourage closure and consolidation of space facilities.

Within NASA and DoD, these budget realities have had several major repercussions. First, budgetary exigencies provide a strong incentive for greater cooperation among the civil, commercial, defense, and national security space programs. Although there has long been some civil and military cooperation, for instance in the Shuttle program, the current work of the national facilities task team is evidence that broader, multiagency cooperation may be increasing.

Second, reduced budgets have forced the need to critically evaluate the status quo. The nation clearly has more resources for space R&D and operations than it can afford and less funding to meet future needs. "Right-sizing" this infrastructure through consolidation and closure of current facilities has been the primary objective of the space facilities task team.

Finally, declining budgets severely inhibit the attention devoted to planning future space needs. Because there is little confidence that funding will be available, forward planning has generally taken the form of modest changes in the status quo, especially for launch vehicles. This caution is reflected in the NFS's conservative approach to advanced planning for future facilities needs. The situation raises the concern that budgetary decisions could create a de facto national space policy that could be detrimental to long-term U.S. space capabilities.

U.S. SPACE STRATEGIES

Through the years, the National Aeronautics and Space Act of 1958 and other national policies guided NASA's mission pursuits. The agency focused on science objectives and on demonstrating the nation's technical prowess through the manned space program. Although NASA has performed strategic planning periodically in the past, such agency-wide strategic planning often was not supported through the budget process. As a result, strategic direction was in effect accomplished by the control of "new starts" by both administrations and congress. It should not be surprising that at times NASA has encountered difficulties, because its allotted budgets have not met its commitments. Although NASA has instituted a planning process that should help anticipate future facility requirements for various NASA enterprises, there has been no clearly proclaimed and accepted national space policy or overall mission statement that could provide guidance for anticipating future facility needs. The problem is not that administrations have not articulated national space policies; it is that these policies were

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[6] *Aeronautics and Space Report of the President, Fiscal Year 1993 Activities*, Washington, D.C.: National Aeronautics and Space Administration, p. 98.

[7] "Aerospace Employment by Product Group," Aerospace Industries Association, December 15, 1993.

not backed by budget actions and, therefore, were often ignored. Accordingly, the frame of reference for the space operations and R&D facilities task groups primarily has been the budget.

The DoD's space strategy has changed over the past decade or so. In the early days of DoD's space program at the height of the Cold War, space was viewed as an indispensable means of surveillance. As the value of these early space assets became clear, broader capabilities in communications, battlefield management, weapons targeting, and reconnaissance have been added. In recent years, the trend has been to integrate space systems into overall warfighting capabilities and force structures. In fact, the capabilities demonstrated in Operation Desert Storm have raised demand for space systems from warfighters in all of the military services. The strategic focus, therefore, is to capitalize on existing space assets, modernize those assets, and learn to apply the resulting capabilities virtually routinely to accomplish military objectives. However, even under these circumstances, budget realities are forcing DoD to balance funding for space systems against that for alternatives such as aircraft. In DoD as well as NASA, budgetary considerations are having a major impact on space strategy.

THE U.S. SPACE MARKET

In the current environment of reduced government spending on space programs and the lack of clear articulation of long-term national objectives in space, it is sometimes assumed that growing commercial investment will offset shrinking government funding. Significant growth in the commercial space sector could have repercussions for facilities needs, so it is important to understand the nature of the domestic space market and the role of commercial space systems.

The overall U.S. space market can be divided into four related but different areas, plus launch vehicles, which are discussed briefly below. These are human space exploration, space science, military and intelligence space systems, and commercial space systems.

Human Space Exploration

NASA has been responsible for launching men and women into space and will continue to be in the future. Because of environmental and safety requirements and the extreme launch reliability mandated by the presence of people, this market segment is truly unique. The hardware is expensive, complex, heavy, and therefore of limited use to unmanned programs. The Shuttle is the only vehicle now used for launching people. Many expensive facilities, such as neutral buoyancy tanks and centrifuges, are part of the program for humans. This market segment is entirely government funded.

Space Science and Applications

Most scientific satellites, space probes, and observatories are funded by government, so they face the same constraints as other discretionary federal programs. Historically, NASA has held the space science program constant at about 20 percent of its budget, which, if continued, will result in lower funding as NASA's budget declines.[8] However, the trend toward smaller, cheaper satellites may create opportunities for commercial applications satellites, that is, communications and remote sensing satellites. For instance, there is growing commercial interest in Earth observation systems, which to date have depended on government funding.

Military and Intelligence Space Systems

Reductions in defense budgets in the last few years have affected funding available for military and intelligence space systems. Lower spending is causing a significant decrease in the number of military and

[8] Some in Congress have expressed concern about the direction of space science funding. When adjusted for inflation, flat budgets for NASA amount to a 20 percent decline in space science spending power over the next four years, with particularly tight budgets for space science at the end of the decade. See, for example, Liz Tucci, "Flat Budget Forecasts Threaten Cuts in Science," *Space News*, April 18-24, 1994, p. 3.

intelligence satellites being developed and launched. (Ironically, these spending reductions are occurring just as the full value of space-based military capability is becoming better understood, as was demonstrated in the Persian Gulf.)

Commercial Space Systems

The commercial communications satellite business appears to be relatively stable. The trend toward miniaturization enables increased capabilities on smaller spacecraft operating in low Earth orbits. In terms of the value of the commercial satellite business, a decline in the number of large commercial satellites could be partially offset by the growth in small-satellite systems.

Several commercial firms are actively developing small satellites (e.g., less than 500 kilograms) and associated small launch vehicles. Although the growth in this segment of the commercial space market is large, it is small in absolute terms and is not expected to stress facilities requirements for some time.

Launch Vehicles

Because of the declining number of projected satellite launches from the United States and the smaller size of many anticipated new satellite systems, there is significant overcapacity in the medium and large launch vehicle production base.[9] Growth in commercial launches will not create sufficient demand to alleviate this situation. Attempts by General Dynamics and Martin Marietta to market commercial variants of Atlas and Titan launch vehicles developed for the government resulted in significant losses to both companies.[10] Causes contributing to the situation are obsolete, manpower-intensive designs and subsidized foreign competition with modern, efficient designs and modes of operation.

Analysis

The relative size of these five business segments is important to understand. Government spending in the military and civil segments far exceeds industry spending in the traditional commercial segment and the emerging small-satellite segment. Currently, the United States averages 30-40 launches per year, of which approximately five are purely commercial. By the end of the decade, the total number of commercial launches worldwide is estimated to be 18 per year, of which only five or six are likely to use U.S. launchers.[11] Thus the launch vehicle segment probably will continue to be predominantly influenced by government requirements.

To further complicate the situation, with stable or declining government spending the number of launches will not be sufficient on any given launcher to reduce per-launch costs. Per-launch costs are determined by both the costs of building the launcher and the costs of operating the launch facility. Fewer launches lower production rates thereby reducing scale economies in the manufacturing process. Fewer launches also reduce the ability to amortize the high fixed costs of operating and maintaining launch facilities. The resulting higher launch costs can consume funds that could otherwise be available for new satellite systems development, which will further reduce demand for launches. This cycle can only be broken if launch costs can be lowered significantly, through large investments to improve the efficiency of launch facilities or to develop new launch technologies. The nation has thus far been unwilling to make such investments.

INTERNATIONAL ENVIRONMENT

Another major change in the conditions facing the U.S. space community that will have effects on facilities decisions is the

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[9] In both the United States and Russia, conversion of ballistic missiles to provide low-cost launch vehicles has been considered. However, the likely impact on facilities would not be significant, and the committee did not consider this issue germane to its charge.

[10] Martin Marietta recently concluded its purchase of General Dynamics' Space Systems Division.

[11] Lt. Gen. Thomas Moorman, Jr., Chairman, DoD Launch Modernization Study, briefing to the committee, March 9, 1994.

growth of foreign space capabilities. Today the other major players in the world space business are Russia, Europe (both through the European Space Agency—a consortium of 14 European nations—and through individual national programs), China, and Japan. Indigenous launch capabilities include Russia's Proton, China's Long March, and Europe's Ariane 4, which are the primary competitors to U.S. launchers. In addition, several European companies, such as British Aerospace, Matra Marconi Space, and Alenia, are highly competitive in the communications satellite market.

The implications for the U.S. space community of these strong and growing foreign capabilities continue to unfold. For both political and economic reasons, foreign launchers are likely to garner increasing global market share, particularly for commercial launches. Despite international agreements on fair pricing and limitations on the number of launches that can be sold (e.g., in the case of Proton and Long March), foreign launch services are often priced below their American competitors. For large, sophisticated satellites, the price of the launch is probably less important than its reliability and scheduling, but for smaller payloads, launch prices may be the most significant factor in choosing a launch supplier.

For government launch customers, who dominate the launch market, domestic launch vehicles and facilities will continue to be the primary choice. In this sector, foreign competition for launches is not a bona fide threat, but the fact that foreign launchers are priced lower demonstrates the possibilities and highlights the inefficiencies of domestic launch services. In a tightening budget environment where high launch costs squeeze out other spending, foreign capabilities may provide an increasingly attractive alternative, even for government customers.

SUMMARY

The environment in which national space activities are conducted has changed significantly in recent years. Technological advances, domestic and foreign policy shifts, economic constraints, and international competition all have affected priorities in the space program and increased options for achieving objectives. These changing conditions need to be considered explicitly before any major decisions in facilities planning can be made with confidence. The relevant issues can be placed into four categories.

1. The roles and missions of NASA and DoD have evolved in a relatively uncoordinated manner, resulting in different operating cultures and approaches to facilities. Declining budgets in both the civil and military space programs will increase pressure for greater cooperation among the relevant agencies. Redefining and clarifying their roles and missions offers opportunities to reduce redundant facilities and increase efficiencies, but cultural differences must be recognized and managed to take advantage of these opportunities effectively.

2. The United States has an excess of space R&D facilities, a great number of which are affiliated with DoD programs and owned by industry. Even in the past expanding space market, the capacity was excessive, driven largely by the competitive process and the desire of every large developmental program to possess its own testing capability. The U.S. government is paying most of the cost of these facilities through industry overhead. Initiatives to close, consolidate, and modernize facilities should consider these private facilities as well as those owned by the government.

3. There are limits to the amount of consolidation of space facilities that can be undertaken without adverse effects on efficiency and capabilities. Some redundancy in R&D facilities is desirable to allow competition that spurs innovative thinking and to provide for contingencies. Some redundancy is also justified in operations facilities. For instance, the need for east- and west-coast launch capabilities will continue into the indefinite future, with obvious duplication of supporting infrastructure. U.S. launch facilities evolved over more than 30 years to support a large variety of systems. Attempts to modify old equipment to satisfy new requirements may respond to near-term budget constraints but be considerably more expensive in the long term and vastly less efficient.

4. A fluctuating and uncertain U.S. launch vehicle posture makes future planning difficult. Foreign competition has newer facilities, is better focused for efficient operations, and has lower prices. Innovative approaches toward launch operations, a subject not discussed in the NFS, will be key to the future competitiveness of U.S. launch capabilities.

In short, the environment within which U.S. space programs are conducted poses significant problems for planning. There is no widely accepted, up-to-date national strategy for dealing with issues that are truly national in nature.[12] Against this background, no decision seems final, and, as a result, any long-term plan is viewed with skepticism. Nonetheless, the many developments in the domestic and international environments for space activities have created unrelenting pressure for change. "Right-sizing" the number and content of U.S. facilities to support a reasonable range of space program alternatives can be an important step in the change process.

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[12] The Clinton Administration released a new U.S. space launch policy on August 5, 1994 that calls for DoD to update expendable launchers and NASA to develop new launch technologies. Because it had not yet been announced, this policy did not appear to affect the NFS.

3

The National Facilities Study

DESCRIPTION OF THE STUDY PROCESS

The NFS is an interagency cooperative effort intended to:

- determine where U.S. facilities do not meet national aerospace needs;
- define new facilities required to make U.S. capabilities world class;
- define where consolidation and phase-out of existing facilities is appropriate; and
- develop a long-term national plan for world-class facility acquisition and shared usage.[13]

To accomplish these objectives, an oversight group, chaired by John Dailey from NASA and vice-chaired by Charles Adolph from DoD, was formed to oversee the work of the interagency task team, directed by Richard Kline. The task team was organized into task groups to examine aeronautics R&D, space R&D, space operations facilities, and facilities costing and engineering. Each of these task groups was supported by working groups in key specialty areas. The task and working groups gathered information on government and industry facilities through interviews and inventory data requests and met periodically during 1993 and early 1994. An industry forum was held at Kennedy Space Center to gather specific company comments.

The approach taken by the task and working groups was simultaneously (1) to define facilities needs based on civil, defense, and commercial mission requirements, and (2) to create a facilities inventory data base that included NASA, DoD, other government, and industrial facilities. The task groups then analyzed the resulting data, comparing facility needs with existing capabilities to determine areas of overlap and underutilization, as well as shortfalls and gaps. It is important to note that this analysis focused on government-owned facilities.[14]

The assessment of facilities needs is based on two mission requirements models, a baseline model and an excursion model. Each model includes projections for the civil, commercial, and defense market sectors. These requirements models are largely based on the results obtained in similar recent studies, such as the Civil Needs Data Base developed as part of the NASA Access to Space Study and the Bottom-Up Review of the DoD conducted in 1993. The baseline requirements model assumes that there will be only selected upgrades to the current expendable launch vehicle (ELV) and Shuttle fleet, and current programs such as Mission to Planet Earth will continue. Excursions to the baseline envision a new cargo-carrying vehicle, a shuttle replacement, and a next-generation launch system (i.e., single stage to orbit). It also envisions launch of the next generation of great observatories, continued military uses, and overall growth in commercial uses of space.

The inventory data base was developed by NASA using a modified version of the Air Force Integrated Technology and Assessment System, which is used to track space hardware. The inventory is intended to capture relevant R&D and operations facilities in all government agencies and industry. At this writing, 78 sites had been surveyed

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[13] These objectives were described to the committee in a briefing by Richard Kline, NFS Task Team director, February 7, 1994.

[14] According to a briefing to the committee on December 10, 1993, the NFS did not address contractor-owned facilities because the task groups believed market forces would dictate consolidations and closures of private facilities.

(11 NASA, 30 DoD, 10 Department of Energy, 3 National Oceanographic and Atmospheric Administration, and 24 industry), containing 1,500 buildings and over 2,800 facilities. (Table 3-1 lists the types of facilities in the inventory.) Data requested include general information on name, location, size, replacement value, utilization rate, type specifications, and performance parameters. Contacts for additional information are also included for each entry.

Table 3-1: Facilities Inventory

Assembly	Mission Operations
Command Destruct	On-Orbit Mission Control Centers
Communications	Operational Simulation/Demonstration
Computational Support/Computer Operations	Operations
Data Archive/Storage	Payload Operations
Environmental Simulation/ Experimentation	Processing
Flight Experiment Ground Support (e.g., Clean Room)	Propulsion Testing
Human Factors/Biomedical	Range
Landing Operations	Recovery Operations
Launch	Research Laboratory
Launch Processing/Operations	Rocket Propulsion Ground Test Facility
Launch Processing/Booster	Support
Launch Processing/Ordnance	Test Chambers
Manufacturing	Test Stands
Materials	Test Beds
	Tracking and Data Acquisition
	Training
	Wind Tunnels

Category 2: Further study is required; the necessary analysis and evaluation are still in progress.

Category 3: No recommendations were made due to lack of data, insufficient time to assess the data, or, in some instances, an initial assessment determined that no significant cost savings could be realized.

All the facilities described in the inventory data base have not been evaluated. Selection for analysis was based on data availability, experience and knowledge of team members, and selected site visits by the working groups.

Based on the mission requirements models, the inventory findings, and additional information gathered through site visits and other studies, the task and working groups assessed opportunities for closure, consolidation, and joint use of government facilities, as well as needed modifications/ upgrades and new facilities. These assessments are presented in a series of recommendations on specific facilities, which fall into the following categories:

Category 1: Assesses the capabilities and condition of the facility and develops a firm recommendation—consolidate, close, modify, transfer, enhance, or no change.

1A: Recommends changes to the status quo or advocates continuing changes that are consistent with NFS objectives.

1B: Recommends no change.

Overall, the members of the task team concluded that mission requirements for the next 30 years can be met with existing facilities, with only minor upgrades and maintenance required. They also concluded that the excursions to the baseline can be met with upgrades and modifications to current facilities. Exceptions would be for extended time on the Moon or human exploration of Mars. In addition, they found overcapacity in some areas of space R&D facilities that could be alleviated through a single national management authority responsible for coordinating usage and pricing. The task team emphasized the point that significant savings from closure and consolidation of facilities to reduce overcapacity can only result by reducing personnel. The point was also made that further review of the roles and missions of the various agencies engaged in space activities could provide the basis for significant cost reductions in the future. The NFS summary recommendations are included in Appendix B.

GENERAL ASSESSMENT OF THE INTERAGENCY REPORT

Given the relatively short time available to the task team and working groups to pull together much information and analysis about the current space facilities infrastructure, the Committee on Space Facilities believes that many aspects of the study were performed very well. The inventory of more than 2,800 facilities will be an important resource especially if it continues to be updated and maintained as the NFS report recommends. Although some important facilities, such as the new Earth-Observing Satellite Landsat command and receiving ground station in Oklahoma and facilities for simulating the natural radiation environment, are not included, and more work is needed to include as many industry facilities as possible, the initial effort to construct the inventory has been strong. The data in the inventory provide the basis for a much better understanding of the resources available in the national facilities infrastructure and extensive information on which to base rational decisions about current and future facilities needs.

The working groups have used the inventory data and other information to make a set of well-reasoned recommendations that include estimates of cost savings and steps for implementation. Because of the current budget environment, however, the requirements models used by the task team envision very little change from the status quo. The recommendations for facilities changes based on these models, therefore, are timid. For instance, in the case of space operations facilities, only 17 percent of the 912 facilities inventoried are affected by the 40 category 1A recommendations for change, while 45 percent received 1B (No Change) recommendations; the remaining 38 percent were category 2 or 3, with no change recommended pending further study or more data.[15]

In the recommendations for change, the emphasis is on reducing annual operating costs by closing some facilities while modifying and consolidating others. Though the potential savings from changes in roles and missions are recognized, such changes are not addressed. Similarly, improving the use of facilities through more consistent pricing policies is a recognized need, but the NFS only suggests further study. Although some new facilities requirements are articulated, the committee believes that there is too little attention to future needs to fulfill that aspect of the NFS objectives.

This general critique of the NFS underlies the Committee on Space Facilities' assessment of the effort. Although the committee recognizes the importance of cutting costs, the space facilities analysis is not well balanced between the restrained approach driven by shrinking budgets and the future vision needed to begin planning for new and upgraded facilities. Some of the needed future analysis could be accomplished by additional reviews; this includes the review of roles and missions to generate future efficiencies and the review of other policies such as pricing. Systematic studies of both of these issues are major recommendations of the task team with which this committee strongly agrees.

If the NFS is ultimately to respond to the questions posed to the task team, more attention to long-term issues, particularly innovative approaches to meeting long-term national objectives in space, is a necessity. The following chapter presents this committee's views and recommendations on specific issues that deserve more attention.

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[15] Space Operations Facilities Task Group, National Facilities Study, Volume 4, Section II.

4

Issues, Findings, and Recommendations

The Committee on Space Facilities reviewed working drafts and the final reports of the NFS. The committee heard briefings from members of the working groups and task team, as well as from other experts with important views relevant to the environment for and objectives of the NFS. Based on this information, the committee believes that the NFS represents a good start at addressing long-neglected issues regarding the national space infrastructure. The recommendations for change are well reasoned, as far as they go, and merit implementation. Additional work is needed, however, and a few areas did not receive the attention this committee believes they deserve. These areas include (1) the requirements models described in the NFS, (2) the efficiencies possible from a serious analysis and realignment of agency roles and missions and management practices, (3) the level of industrial participation in the space facilities aspects of the NFS, and (4) the implications of future international competition and cooperation for domestic space facilities.

REQUIREMENTS

In an ideal world, facility requirements would be determined through a process that would begin with a national space policy and proceed through agency strategic plans to planned programs that would require a set of facility capabilities. Since such long-range policy and plans do not currently exist, the interagency task team used baseline and excursion mission requirements models that are based on recent studies and policy decisions that reflect current budget constraints.

The futures projected by these requirements models envision little change from the status quo. The baseline model for commercial, civil, and military needs for space systems takes the approach that current U.S. programs and facilities, for example, large ELVs, communication satellites, and Earth-observing satellites, are adequate for current and near-term future needs. The baseline model assumes that the present fleet of Space Shuttles and ELVs, with modest upgrades, will be used through 2023. While one or more new families of small, low-cost launch vehicles are assumed to become operational during this decade, no new large launch vehicles are assumed for the next three decades. Since the baseline requirements model contains no new major missions or vehicles, the NFS task team assumes that no major changes in launch facilities or research facilities are needed. Similarly, no significant advances in space technology are viewed as necessary.

While the excursion requirements model is somewhat more forward-looking, the committee believes that the NFS authors were unduly cautious. The excursions presented contain missions that have been previously advocated but would require major funding increments and are beyond the scope of a level-of-effort space program, as well as new large launch vehicles in the 2003-2008 time period. Specifically, the following new launch vehicles are assumed:

1. A new nonpiloted cargo vehicle in the commercial sector;
2. A new highly reusable launch vehicle for crew and cargo in the civilian government sector; and
3. A new nonpiloted cargo vehicle in the defense sector.

The impacts of the excursion model are not addressed in depth by the NFS. The study points out that facilities required to support implementation of the launch system excursion, which includes a new single-stage-to-orbit launch vehicle, are dependent on the specific configuration being developed. It then states that the requirements of most concepts can be met by modifications to existing facilities. Regarding R&D facilities, it states that mission model excursions can be met mostly by upgrades and/or modifications to existing facilities. The study notes that manned planetary missions would require new facilities, with the most costly being those required for nuclear propulsion development.

Assessment of Mission Requirements Models

The baseline model is not deemed by the committee to be adequate as a basis for long-term planning. As noted above, the model is based on other recent studies and conforms to current budgetary and political decisions. It assumes that the status quo will be maintained for the next 30 years. In fact, it is much more likely that the space program will undergo major changes in direction and scope during that period. The committee believes that the excursion model is more indicative of what is likely to be needed during this 30-year period since it explores the development of some new facilities and technology. A fundamental question arising from an assessment of the NFS baseline model is, "What are the possible long-term outcomes of the baseline assumptions?" The committee suggests the following:

- With no new ELVs or changes in launch facilities, continued operational inefficiencies will drive up launch costs, thereby squeezing out investment in new payloads. For both the military and civil space programs, launches will be much more expensive than they could or should be.
- As foreign entities continue to build relatively cheap and reliable launch capabilities, utilization of existing U.S. ELVs will clearly diminish. Due to time and cost advantages, a number of U.S. entities are already launching satellites using foreign launch facilities. This trend will continue in the absence of domestic development of new, medium- or large-payload launch vehicles and capabilities.
- Although the development of small-payload, low-cost ELVs is reasonable as a baseline assumption, the committee believes that this type of vehicle is not likely to capture a large share of the overall worldwide launch market and will not have significant impact on facilities requirements.
- Simply continuing the status quo with modest upgrades of radio-frequency geostationary telecommunications satellite systems and Earth-observing/remote-sensing systems could lead to a situation similar to that of large ELVs: foreign development could overtake U.S. dominance in satellite operations.

None of these potential outcomes is outlined in the NFS report. The implications of the baseline model for U.S. space autonomy, economic competitiveness, and national security have not been clearly defined.

Assessment of Facility Requirements

The committee is concerned that the baseline and excursion requirements models presented in the report have resulted in inadequate treatment of operations facilities. Based on the models, no new operations facilities were deemed to be required, no major upgrades or modifications to operations facilities were proposed, and no potential innovative approaches were explored. This criticism is especially relevant to launch facilities.

The present U.S. launch facilities were originally constructed as **development** facilities as part of the evolving U.S. space program. In their design, with the exception of the Space Shuttle, little emphasis was placed on **operational** efficiency. Compared with modern launch facilities such as the Arianespace launch complex in Kourou, U.S. launch facilities are antiquated, inefficient, costly to operate, and require extremely large work forces.[16] In order for the United States to compete in the world

[16] See also, Aeronautics and Space Engineering Board, *From Earth to Orbit: An Assessment of Transportation Options*, Washington: National Academy Press, 1992.

launch vehicle market, major upgrades and revisions are required to incorporate modern automation and information technologies and to streamline payload integration and launch procedures.

This issue is not addressed in the present study. In fact, a major overall goal of the NFS is not addressed: "To allow us to impact external budget submissions, as appropriate . . .to ensure. . .the proper infrastructure for our nation's aerospace industry to remain the world's leader."[17] Because the baseline model (and current policy) emphasizes maintaining the status quo, the costs associated with current launch inefficiencies are not recognized and the lessons possible from reviewing the operations of modern launch facilities abroad are not included in the analysis. Such a critical evaluation is necessary to develop effective recommendations to ensure competitive U.S. launch capabilities in the future.

Recommendations

Based on this assessment of the mission and requirements models and the analysis of facilities needs based on the models, the committee recommends the following:

Because 30 years without any new launch vehicle is not realistic, the baseline requirements model should be revised to include a major new launch vehicle or family of vehicles. For each vehicle, requirements for assembly facilities, payload integration facilities, launch pad, and mission operations facilities should be assessed to maximize operational effectiveness. This vehicle family could encompass all the missions that are presently captured by the new nonpiloted cargo vehicle in the Commercial Space excursion model and the new highly reusable launch cargo vehicle in the DoD excursion model. A number of possible approaches are currently being evaluated to upgrade and modernize U.S. launch capabilities, including single stage to orbit, liquid and solid technologies, and hybrids of the two. Regardless of the technology employed, any new vehicle line should be designed from the outset to be an operational system using revised management practices, as well as new automation and information technologies, to minimize the required personnel. In addition, the technologies used should be sufficiently robust to minimize the risk of problems that could ground the fleet.

A follow-on study should assess the long-term trade-off between modifying present operational facilities and constructing new innovative operational facilities to achieve the launch cost reductions that are mentioned in the revised requirements models. A new set of R&D facility requirements, consistent with the revised requirements models, should be developed and presented to the NFS oversight group.

Also, a new set of required operational facility upgrades and construction, consistent with the new launch vehicles and the study mentioned above, should be developed and presented to the NFS oversight group. In the case of planetary missions, facility needs should not be predicated on the sole assumption that nuclear propulsion will be used. Instead, facility needs corresponding to other viable approaches (e.g., chemical/aerobraking for manned missions, solar electric propulsion for cargo missions, use of in situ resources for propellant and other consumables) should be presented in a set of options along with those corresponding to nuclear propulsion.

ROLES, MISSIONS, AND MANAGEMENT CONSIDERATIONS

The NFS accomplished the most complete cataloging and assessment of space facilities to date. However, the changes recommended by the NFS may represent only the tip of the iceberg of potential savings. The financial calculations used to estimate savings from closures and consolidations are based only on avoiding the costs of facilities operations. Significant savings and improvements in the effectiveness of capacity utilization and future investment decisions could be achieved if the study were expanded to consider changes in

[17] Letter from Daniel Goldin, NASA Administrator, to Donald J. Atwood, Deputy Secretary of Defense, November 13, 1992.

program management and in roles and missions between agencies.

The NFS did include a working group to address the need to review the roles and functions of different agencies. It recognized that realignment of roles and missions may be key to major, visionary changes in national space activities. There is brief mention of these issues and suggestions for further review, but they do not receive the attention this committee believes they deserve considering the potentially high payoff. The committee recognizes, however, that effective realignment of agency roles and missions would require strong leadership from the White House.

Roles and Missions of NASA Centers

One area not specifically addressed in the NFS report concerns opportunities to consolidate activities of the NASA Centers, which have numerous overlaps in facilities and capabilities. For example, there are flight operations at Johnson Space Center, Marshall Space Flight Center, Goddard Space Flight Center, the Jet Propulsion Laboratory, and other locations. Similarly, a number of centers conduct work on space robotics, sometimes without a critical mass. Ames Research Center and Johnson Space Center both have historically performed work in the life science field, and they have developed separate space suits. Such overlaps evolved during a period of robust budgets. With the current budget constraints, most of this duplication probably is not justified, though some may be warranted to provide desirable redundant capabilities and to stimulate competition and innovation. Consolidation would allow personnel reductions and save on facility operations.

In assessing possible consolidation of NASA centers, however, care should be taken not to consider facility costs as the only decision criterion. Only similar operations with common operational philosophies should be colocated. For example, at Johnson Space Center, crew and hardware safety is the driving requirement. Placing science and experiment operations with the same group may result in more complex procedures, because there may be a tendency to apply the same requirements and processes across the board.

Shuttle Operations

Early drafts of the NFS report included a recommendation by the Space Operations working group to eliminate use of Rockwell's Palmdale plant for Shuttle assembly, modifications, and inspection, and for thermal protection system tile and blanket production. These activities would be moved to Kennedy Space Center (KSC). As a result of a request by Congress to reassess the decision to close Palmdale, the final NFS report removed this recommendation, instead suggesting that the issue receive further study.[18] This decision should not cause NASA to abandon the idea of consolidating most Shuttle hardware activities at KSC. Further study should include estimates of the savings in facilities and programs that could occur through such consolidation. These are far more substantial than the annual savings previously estimated based on direct cost avoidance only: $1.5 million in occupancy costs and $35-40 million in operations labor.[19]

NASA is not planning to build additional orbiters. Most of the flight hardware is at KSC and with time the expertise on the hardware will migrate to where the hardware is operated. Moving the management of the systems to the operating location would have the effect of making management more operationally oriented. The move from a development to operational philosophy would result in lower cost over time. However, the long-term value of making KSC more operationally oriented is not recognized in the NFS report, so the potential savings from such a programmatic change are not discussed.

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[18] On March 15, 1994, NASA announced that all major modifications to Shuttle will continue to be made at Palmdale, following a detailed analysis of the savings from moving the work to KSC.

[19] Savings estimates made by the Manufacturing Working Group, Space Operations Facilities Task Group, in a draft category IA recommendation of November 16, 1993.

This example is a good illustration of the factors beyond short-term operating costs that affect closure and consolidation decisions. Strong political pressures can be brought to bear to keep any federal facility operating after its usefulness has ended. To overcome such pressures, an approach similar to that of the recent Base Realignment and Closure Commission would appear to be reasonable.

Air Force Launch Operations

The Air Force has made major organizational changes by separating development and operations of space launch systems. It has established an Air Force operating squadron for each of the three launch vehicles: Titan, Atlas, and Delta. Each squadron oversees the actual operations that are managed by different development contractors. None of these vehicles was originally designed to optimize operations, and mechanisms to make them more operational should be explored. For instance, designating a single operations contractor for all systems could result in significant savings assuming current impediments to such an approach could be overcome. Based on the Space Shuttle experience—shuttle operations are not managed by the developer—such a change could be made with no loss of reliability or availability.

Management Considerations

Many recent studies regarding the U.S. competitive posture in the launch vehicle market point to differences in the management approaches used in other countries. For example, a NASA comparison of the Ariane V solid rocket motor development with that of the U.S. Advanced Solid Rocket Motor shows very similar design and technology but much lower development and production costs for Ariane.[20] Part of this cost difference is due to differences in missions and the level of political involvement, but management philosophy and certification requirements are also major cost drivers in the United States. A committee of congressional staff members reached similar conclusions.[21]

Roles and Missions Between Agencies

In view of the budget pressures on both NASA and DoD, changes in their respective roles and missions should be studied further. An important example concerns KSC and the Air Force 45th Space Wing at Cape Canaveral. Now sharing a common strip of government property, they share the same primary purpose: successful launch of space vehicles. The NFS views favorably the shared contracts between the two organizations and commends the coordination achieved through the Air Force/NASA liaison team at the Cape. However, the study does not consider whether additional savings could be achieved were the base operations of the launch facilities at Cape Canaveral merged. Such a management change deserves further study to identify specific areas in which a merger would make sense and to estimate the potential economies.

If such consolidations were implemented, it should be strictly for base operations and separated from the development organizations of both agencies. It should focus on maintenance, logistics, and personnel requirements that are common to both customers, regardless of the vehicle being launched. Examples of savings might include a single management structure, one guard force, one fire-fighting force, and one contractor for base operations.

Recommendations

Using the recommendations in the NFS as a baseline, additional study is needed of the total savings possible from effective consolidation and management streamlining of NASA and DoD space programs. This

[20] Russ Bardos, "A Comparison of Ariane 5(Solid) vs. Shuttle Advanced Solid Rocket Motor (ASRM) Development/Production," briefing to the NRC Committee on Space Facilities, February 7, 1994.

[21] Terry Dawson, "Space Launch Oversight Trip Report—August 23-September 3, 1993," briefing to the committee, March 9, 1994.

expanded study will undoubtedly indicate that greater savings are possible when appropriate program changes are taken into account and will make the closing of any facility easier to justify.

NASA and DoD should initiate in-depth analyses of their respective roles and missions. Opportunities to increase the total effectiveness of national space efforts, as well as to improve efficiencies at specific facilities, should be identified and appropriate actions initiated. Integration of operational responsibilities should be achieved wherever possible. This process should be overseen by the Executive Office of the President.

Because a broad revision of roles and missions would result in extensive changes in facilities requirements and workloads, and would likely raise political concerns, consideration should be given to establishing a presidential commission, analogous to the Base Realignment and Closure Commission, to help generate the political consensus necessary to implement some facilities closure and consolidation recommendations.

INDUSTRIAL PARTICIPATION

Another shortcoming of the NFS analysis of space R&D and operations facilities is that, unlike the analysis of aeronautics facilities, it did not include industry representatives to help evaluate several issues important to both industry and government. This inconsistency prompted the committee to question the task team's level of understanding of industry concerns about right-sizing space facilities and the economic and competitive impact of any policy changes resulting from the final report of the NFS.

Because the NFS focused on government-owned facilities, the study has not taken adequate account of major private facilities. There is no analysis of how facilities in industry compare with each other or with comparable facilities in government, in terms of age, capabilities, cost, level of use, support requirements, and other factors. Such an assessment would be very valuable for generating a comprehensive, long-term plan for space facilities.

Further, neither the mission model nor the analysis of facilities to support the mission model provided sufficient consideration of commercial ventures in the private sector. Many aerospace contractors are taking their strong core competencies to the commercial marketplace to offset cuts in the federal budget. The use of existing space facilities in the pursuit of commercial activities needs to be encouraged.

This relative inattention to private facilities in the NFS is apparently due to the belief by the task groups that market forces would dictate decisions on private facilities. Although the aerospace industry is going through a period of significant consolidation as a result of reduced defense spending, economic incentives are such that considerable excess capacity in space facilities may remain. The industry is concerned with the economics of space facility closure, regarding both financial liability considerations and future business. Appropriate legislation could eliminate the tax liabilities and provide economic incentives for mothballing or closing a space facility. Further, companies must be assured that closing facilities would not disadvantage them in future contract competitions. Much better access to remaining facilities, whether government or industry owned, must be assured before contractors will be sufficiently confident to close their underused facilities.

Although an individual company's facilities may be required for the company to appear competitive to the U.S. government on any future procurement, the prospects for future government work are dim and uncertain. Industry well understands that the major share of U.S. space efforts is controlled by the government. Thus, company initiatives to close, modernize, or replace facilities can only be undertaken with appropriate government incentives and some assurances that government-sponsored demand will be reasonably predictable. It is essential, therefore, that proposed solutions to reduce the number of space facilities be derived through close cooperation with industry, recognizing industrial constraints and concerns. Even more important, assurances are needed that government will not undertake its own initiatives that compete with those of private industry.

These issues may be responsible for the relatively sparse participation by industry in the facilities inventory. Contractors may be concerned that if their facilities are included in the inventory, they would be more likely to be targeted for closure or consolidation, thereby placing the company in a disadvantaged position for winning future business. This issue can only be addressed by having much broader participation by industry representatives in the analysis and decision-making process.

Recommendations

The post Cold War de-emphasis on space research and its effects on the space industry should be closely monitored. Therefore, concerted efforts are needed to enhance industry participation in the space R&D and operations aspects of the NFS, to match its participation in the aeronautics study. Industrial representatives could assist in identifying the trade-offs necessary to determine which industry facilities are needed in the future, which facilities should be retired, and which should be extensively modified. Therefore, the committee strongly recommends the following:

The NASA/DoD study should continue into a second phase with strong involvement from the aerospace industry. In addition, it would be useful to include representatives with expertise in economics, tax policy, and policies affecting commercial use of space.

If a second phase is added to the study, every effort should be made to evaluate the degree to which facilities can enhance the ability to effectively achieve future missions. One approach that should be considered is to develop a comparative matrix of capabilities with an assigned merit system that values each facility according to its ability to meet future program requirements. There should not be any bias towards government facilities in making total or partial closure recommendations. Where possible, future mission models should be defined to include consideration of commercial uses of space.

The NASA/DoD interagency team should address the economic and business development incentives and disincentives facing private contractors when they consider closing, mothballing, or building facilities. Specific policy changes should be identified that would encourage rationalization of private facilities by making decisions on facilities financially attractive.

INTERNATIONAL COMPETITION AND COOPERATION

A fact inadequately considered by the NFS is that modern space facilities exist throughout the world. Many foreign launch facilities are newer and, having benefited from American experience, are designed for operational efficiency and cost-effectiveness. Over the next 30 years, foreign capabilities will undoubtedly continue to improve and expand. Foreign facilities will affect U.S. space operations and R&D efforts either by providing opportunities for cooperation or by creating sources of competition for U.S. facilities and setting standards for cost, reliability, and capability. Foreign developments, therefore, should be factored into future U.S. facilities planning.

Foreign Capabilities

Among spacefaring nations other than the United States, Russia has the most experience and the largest, most comprehensive space program. For many years, the space program of the former Soviet Union was designed to create national prestige and to support military security. Since the end of the Cold War, the Russian space program has been evolving along two tracks.

First, to raise money, Russia has made available for sale to the world a significant amount of technology as well as hardware and launch services. These include new technology such as Stationary Plasma Thrusters, as well as existing hardware including Proton boosters, rocket engines, and Soyuz modules.

Second, Russia has continued the space station program started with Mir and evolved it into an international space station program with the United States. This program is motivated not only by economics but also by national prestige and as a way to cement ties with the United States. It is reasonable to assume that the Russian effort in space will continue along these two tracks for some time.

The European Space Agency and various national space programs have built a modern space capability for Europe. Europe is heavily involved in international cooperative programs with the United States and Russia. These programs range from various types of scientific satellites to participation in the international space station. Part of the European program, therefore, is geared to cooperative ventures. However, the European Space Agency has developed the Ariane 4 ELV and is developing the Ariane 5. In 1993, Ariane 4 was the commercial market leader, with seven commercial satellite launches. In the area of satellites, companies such as British Aerospace, Matra Marconi Space, and Alenia have significant capabilities in manufacturing communication satellites. Therefore, parts of the European national programs form significant competition for the United States.

The Chinese space program offers low-cost services for launching satellites. The prices offered on these launchers are significantly lower than comparable U.S. launchers. Despite pending trade agreements requiring the Chinese to sell Long March rockets on a par with Western bids, they have been underbidding by 30 percent.[22] A new agreement is expected to be negotiated this year, but the Chinese will remain important competition for future commercial launches.

The Japanese continue to develop indigenous satellite technologies. Their announced strategy is to develop the capability for autonomous activities in space, including design and manufacturing, and actively to promote and participate in space projects involving international cooperation. The latter goal is being met through involvement in the international space station and several international scientific missions. The Japanese space program has recently achieved its long-stated goal of domestic autonomy in launchers with the launch of the H-2 rocket. While it is possible that the Japanese program may develop a strong and competitive commercial component, significant difficulties remain to be resolved. (For instance, the H-2 can be launched only during two 45-day periods in the winter and summer, limiting the number of launches to 4 or 5 per year, and the high latitude of the launch site at 30.2 degrees currently limits the net payload that can be placed into final geostationary orbit to 2 tons.)

Competition or Cooperation

The extent to which the United States should compete or cooperate with foreign space programs depends on national objectives and policy. U.S. policy, although not always clearly stated, can be inferred from government actions. By examining U.S. actions in the space market segments discussed earlier, some interesting conclusions about national policy can be reached.

Human Space Exploration

Sending people into space is becoming increasingly cooperative due to foreign policy considerations and domestic funding constraints. Currently, the most prominent area of international cooperation is the international space station. The European Space Agency, Italy, Japan, and Canada are developing hardware for integration into the space station, and Russia and the United States have agreed to cooperate extensively in the space station program.

Launch support for human space flight is becoming as internationally cooperative as the manned space program itself. Of the 34 projected launches needed to complete assembly of the space station, 21 currently are scheduled to be U.S. Shuttle launches and 13 to be Russian launches.[23] Also, it has been suggested that Ariane be used to carry equipment to the space station.

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22 Patrick Seitz, "U.S. Officials Probe Proton, Long March Pricing Policies," *Space News*, vol. 5, no. 10, March 7-13, 1994, p. 12.

23 Additional flights are projected for use of the space station prior to completion of assembly. In total, 72 flights are projected through completion of assembly, of which 28 will be by Shuttle and 44 by various Russian vehicles. See, NASA Systems Design Review, March 23, 1994.

Space Science and Applications

International cooperation is extensive in this segment. Within the international scientific community, missions are planned to be complementary whenever possible. The development of space platforms and scientific instruments is also designed to maximize the return on investment. Most scientific satellites are truly international, with many countries contributing scientific instruments for a single mission. It is fairly common for the United States to provide components and instruments to be integrated into foreign spacecraft and then tested at foreign facilities.

The International Solar Terrestrial Physics program alone provides a number of examples. For instance, for the Solar Heliospheric Observatory, the United States is providing the Michaelson Doppler Interferometer for solar seismology, an Ultraviolet Coronal Spectrograph, and a White Light Coronagraph. These instruments will be integrated by Matra and tested at the Centre National d'Études Spatial facility in Toulouse, France.

Military and Intelligence Satellites

The national capability to design, build, and operate this class of satellite must be maintained, independent of any foreign assistance. The United States will therefore maintain all facilities required to support its military and intelligence missions. International cooperation will be very limited.

Commercial Space Systems

The commercial satellite business is driven by cost and new technology. The United States has a substantial lead in payload technology and spacecraft design, which are the critical factors in determining competitiveness in the market. This market is much like the commercial aircraft market in that companies must invest in the required technology if they are to maintain market share. Similarly, to gain foreign sales, contract bids increasingly will be made by international teams of companies and include more foreign suppliers. Overall, international competition is much more prevalent than cooperation in the commercial space market.

The emerging subsection of the commercial market, micro satellites and their associated small launch vehicles, remains immature and difficult to predict. So far, decisions seem to be driven by commercial factors, and the United States is developing market leadership. Here, also, international competition is likely to become more prevalent than cooperation.

Launch Vehicles

In this market segment, recent federal budget constraints are such that modifications and improvements to launch systems have been limited to those that have near-term payoff or are required to replace obsolete components that cannot be procured or maintained. These budget constraints are reflected in the mission requirements models in the NFS. As stated previously, the committee believes that this lack of investment in launch vehicles will result in the United States losing its remaining commercial satellite launch business to foreign launch vehicles, and in the remaining U.S. government customers paying more than world prices for launch services.

The current environment of competition with foreign launchers may, therefore, give way to greater international cooperation on launch facilities and vehicles.[24] As a word of caution, if the United States turns to foreign launch services, it would probably take even longer for the U.S. industry to recover, if necessary, than after the decision to use only the Space Shuttle for launching satellites.

Conclusions

In virtually every aspect of the space market, foreign capabilities are improving. In

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24 Edward C. Aldridge, Jr., president and chief executive officer of The Aerospace Corporation, presented the notion of an international cooperative effort for development of the next generation reusable launch vehicle in a speech at the U.S. Space Foundation Symposium, Colorado Springs, Colorado, April 6, 1994.

two sectors, human space exploration and space science, better foreign capabilities make international cooperation advantageous and are a cost-effective approach to meeting both U.S. and international objectives. In the other sectors, especially in launch vehicles, competition is prevalent. Based on current policies, foreign launch vehicles and facilities will continue to set the world standard and therefore gain more of the world market. U.S. government launches will remain in the country but face a cost penalty that may eventually force more use of foreign launches, with the likely notable exception of military and intelligence payloads. Foreign R&D facilities also will continue to improve, perhaps providing cost advantages in this area as well.

Given current international trends, any comprehensive, long-term evaluation of U.S. facilities needs must consider foreign capabilities. Major foreign facilities should be included in the inventory, including data on their capabilities, usage, and costs, and on comparable facilities in the United States.

Just as with domestic facilities, major foreign capabilities should be consistently tracked to provide credible assessments of the current state of the art in various types and classes of facilities. In cases where foreign facilities set the world standard, assessments should be made regarding whether a similar capability is needed in the United States or whether sufficient access to secure use of the foreign facility is available to domestic users. In some cases, it may be appropriate and feasible for a U.S. contractor to purchase or to acquire operational control of a foreign facility.[25]

[25] For example, an American company recently acquired operational control of the German Space Test Facility near Munich.

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Summary of Recommendations

Based on the assessment of the NFS by the Committee on Space Facilities, several recommendations for improvement and continued study have been made. In virtually every case, the committee's recommendations are driven by the clear need to be more realistic both in recognizing current incentives and disincentives in the aerospace industry and in forecasting future conditions for U.S. space activities. In today's budget-conscious environment, it is natural that the NFS focused on cost reduction and consolidations. Yet, such a study is only useful to future planning if it gives equal weight to guiding the direction of future facilities needed to satisfy legitimate national aspirations. Even in the context of cost reduction through facilities closures and consolidations, the study is timid in recognizing and proposing program changes and realignments of roles and missions to capture what could be significant savings and increased effectiveness. With this context in mind, the committee makes the following 11 recommendations:

Recommendation 1. Because 30 years without any new launch vehicle is not realistic, the baseline requirements model should be revised to include a major new launch vehicle or family of vehicles. For each vehicle, requirements for assembly facilities, payload integration facilities, launch pad, and mission operations facilities should be assessed to maximize operational effectiveness. This vehicle family could encompass all the missions that are presently captured by the new nonpiloted cargo vehicle in the NFS commercial space excursion model and the new highly reusable launch cargo vehicle in the DoD excursion model. A number of possible approaches are currently being evaluated to upgrade and modernize U.S. launch capabilities, including single stage to orbit, liquid and solid technologies, and hybrids of the two. Regardless of the technology employed, any new vehicle line should be designed from the outset to be an operational system using revised management practices, as well as new automation and information technologies, to minimize the required personnel complement. In addition, the technologies used should be sufficiently robust to minimize the risk of problems that could ground the fleet.

Recommendation 2. A follow-on study should be performed to assess the long-term trade-off between modifying present operational facilities and constructing new innovative operational facilities to achieve the launch cost reductions mentioned in the revised requirements models. A new set of R&D facility requirements, consistent with the requirements models, should be developed and presented to the NFS oversight group.

Recommendation 3. A new set of required operational facility upgrades and construction, consistent with the new launch vehicles and the study mentioned above, should be developed and presented to the NFS oversight group.

Recommendation 4. Using the recommendations in the NFS as a baseline, additional study is needed of the total savings possible from effective consolidation and management streamlining of NASA and DoD space programs. This expanded study will undoubtedly indicate that greater savings are possible when appropriate program changes are taken into account and will make the closing of any facility easier to justify.

Recommendation 5. NASA and DoD should initiate in-depth analyses of their individual roles and missions. Opportunities to increase the total effectiveness of national space efforts, as well as to improve efficiencies at specific facilities, should be identified and appropriate actions initiated. Integration of operational responsibilities should be achieved wherever possible. This process should be overseen by the Executive Office of the President.

Recommendation 6. Because a broad revision of roles and missions would result in extensive changes in facilities requirements and workloads, and would likely raise political concerns, consideration should be given to establishing a presidential commission, analogous to the Base Realignment and Closure Commission, to help generate the political consensus necessary to implement some facilities closure and consolidation recommendations.

Recommendation 7. The NASA/DoD study should continue into a second phase with strong involvement from the aerospace industry. In addition, it would be useful to include representatives with expertise in economics, tax policy, and policies affecting commercial use of space.

Recommendation 8. If a second phase is added to the study, every effort should be given to evaluate the degree to which facilities can enhance the ability to effectively achieve future missions. One approach that should be considered is to develop a comparative matrix of capabilities with an assigned merit system that values each facility according to its ability to meet future program requirements. There should not be any bias toward government facilities in making total or partial closure recommendations. Where possible, future mission models should be defined to include consideration of commercial uses of space.

Recommendation 9. The NASA/DoD interagency team should address the economic and business development incentives and disincentives facing private contractors when they consider closing, mothballing, or building facilities. Specific policy changes should be identified that would encourage rationalization of private facilities by making decisions on facilities financially attractive.

Recommendation 10. Given current international trends, any comprehensive, long-term evaluation of U.S. facilities needs must consider foreign capabilities. Major foreign facilities should be included in the inventory, including data on their capabilities, usage, and costs, and on comparable facilities in the United States.

Recommendation 11. Just as with domestic facilities, foreign capabilities should be consistently tracked to provide credible assessments of the current state of the art in various types and classes of major facilities. In cases where foreign facilities set the world standard, assessments should be made regarding whether a similar capability is needed in the United States or whether sufficient access to secure use of the foreign facility is available to domestic users.

In closing, the Committee on Space Facilities believes important first steps have been taken toward assessing and streamlining space R&D and operations facilities. However, extensive follow-up measures are needed to take advantage of existing opportunities both to cut costs and to modernize the U.S. space infrastructure.

Appendix A: Statement of Task

The United States is increasingly challenged by advances in technologies that will affect its global competitiveness in virtually all economic sectors. Preeminent among these are advances in aerospace technology. Technological advances are paced by modern, highly productive research and development (R&D), and operational facilities. An interagency task force is conducting a study of national space R&D and operational facilities in order to develop a National Facilities Plan. This plan is scheduled to be developed by spring, 1994. The Aeronautics and Space Engineering Board (ASEB) has been requested to review the interagency facilities plan in two phases. To fulfill this request, the ASEB proposes to assemble a committee of approximately 12 senior experts with a broad knowledge of space R&D, operations, and their associated facilities.

In Phase I the Committee will:

- Review and critique the requirements presented in the national facilities plan for space R&D and operations.
- Review and critique the facility approaches presented in the national facility plan, focusing on technical issues.
- Assess the extent to which the interagency task force has considered alternative facility approaches and alternative ways that recommended facility needs might be addressed, such as by the joint use of industry and government facilities, or by pooling resources internationally in the construction of new facilities or in new practices that would make the use of foreign facilities more amenable.
- Assess whether the interagency conclusions and recommendations are adequately supported by evidence and analyses;
- Recommend any further actions or studies that should be pursued by the interagency group.

Phase II anticipates that continued facilities planning, from a broader perspective, will be required following Phase I. In Phase II, the Committee will:

- Identify a set of possible major federal and commercial initiatives for coming decades, and identify the options that could enable appropriate facility development to address those initiatives.
- Examine the potential effect of various facilities decisions in either enabling or foreclosing future space program options.
- Consider innovative approaches to meeting facility needs beyond the interagency approach, including potential use of foreign facilities.

Appendix B: Major Recommendations of the National Facilities Study

AERONAUTICS[26]

Two new wind tunnels should be constructed by 2002 for commercial jet transport development. Non-traditional approaches should be considered for obtaining this critically needed capability. Legislation patterned after the "Unitary Plan," which was enacted previously for commercially oriented wind tunnel acquisition, is one option. Tax incentives are another. Since the new capability is targeted so strongly toward industry needs, industry could have a much greater involvement in the venture.

Geographical location of the new wind tunnels merits careful consideration because they are expected to be in service for decades. A "level playing field" should be established to evaluate various locations on their technical merits with strong weighting of factors which help keep operating costs low.

SPACE

Seventy recommended options for improved effectiveness should be considered for implementation. They can be accomplished without significant roles and mission changes. *The responsible organizations should review the NFS consolidation/closure findings in Volumes 4 and 5 and develop implementation plans for each option.* Representatives from the NFS Task Groups will assist in the process as desired.

The government and aerospace industry can take additional steps to streamline and focus the Nation's space facilities in this austere budget environment.

National facility planning is clearly affected by national objectives which are being reshaped in recognition of the changing needs in defense and in the civil and commercial sectors. *The need exists for a national vision and underlying policy for space.* It was observed that during this period of dramatic downsizing of all participating departments and agencies, the roles and missions of the agencies as currently established has, in some cases, produced an overlap of functions and responsibilities. This was a limiting factor in defining some facility improvements or savings/decommissioning. Nonetheless, the review concentrated on the best technical approaches and opportunities which might guide future strategic planning. The agency heads may want to jointly review overlapping functions and responsibilities to determine if and where greater efficiencies/cost reduction could result without impacting negatively on the agency missions.

The NASA/DoD/Commercial Mission and Requirements Model document should have long-term value for organizations developing strategic plans involving facilities and their usage. *The mission model should be updated annually and made available to organizations involved in the planning process.*

GENERAL

Facility pricing presents barriers

Although charging policy variations did not have a first order effect on facility

[26]This appendix is quoted directly from, *National Facilities Study Summary Report*, April 29, 1994, p. 23.

recommendations, facility charging policies merit a more systematic look than was possible in the current study. For example, charging policies for launch industry's decisions on use of government facilities. *Facility pricing and practices of DoD, DOC, DOE, and NASA should be the subject of an in-depth review with the objective of developing uniform policy that encourages the most cost-effective commercial and interagency shared use of U.S. government facilities.*

NFS Inventory should be utilized

An up-to-date facilities database is needed when program and budget decisions are made. Effort should be made to collect data missing from NFS Database and thus maximize its value as a unique reference asset. *The database should be institutionalized in a proper form and maintained by the affected agencies on a permanent basis for future reference by both government and, where appropriate, industry.* The database will prove particularly useful to the organizations responsible for implementing the NFS facility disposition recommendations and will assist in making decisions regarding the need for facilities.

Multi-agency facility coordination process is needed

NASA, DoD, DoE agency-level processes should be modified to promote systematic assessment of cost-effective facilities utilization. Strengthened agency-level processes are needed to ensure consideration of interagency options for joint use, alteration, consolidation and/or closure. The National Facilities Study should be institutionalized by assigning a headquarters-level organization in each agency to be responsible for facility assessments and establishing a multi-agency coordination process for facility use and disposition.